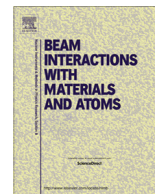




Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimbStructural, magnetic and magnetoelectric studies of BaTiO₃:Co nanocomposite films formed by ion-beam methodsN.I. Khalitov^{a,*}, V.F. Valeev^a, I.A. Faizrakhmanov^a, R.I. Khaibullin^{a,b}, P.A. Gorbatova^b, V.V. Parfenov^b, K.E. Prikhodko^c, V.V. Roddatis^c, M.Yu. Presniakov^c, M. Maksutoglu^d, F.A. Mikailzade^{d,e}^a Kazan Physical-Technical Institute of RAS, Sibirsky Trakt 10/7, 420029 Kazan, Russia^b Kazan Federal University, Kremlevskaya 18, 420008 Kazan, Russia^c National Research Centre "Kurchatov Institute", pl. Kurchatova 1, Moscow 123182, Russia^d Department of Physics, Gebze Institute of Technology, 41400 Kocaeli, Turkey^e Institute of Physics, Azerbaijan National Academy of Sciences, pr. H. Javid 33, Baku AZ1141, Azerbaijan

ARTICLE INFO

Article history:

Received 15 October 2013

Received in revised form 24 January 2014

Accepted 25 January 2014

Available online 13 March 2014

Keywords:

Multiferroics

Ion implantation

Ion beam sputtering deposition

Barium titanate

ABSTRACT

Thin-film samples of ferroelectric barium titanate (BaTiO₃) with cobalt nanoparticles were obtained by using either ion implantation or ion beam sputtering deposition (IBSD) techniques. The samples were characterized using X-ray diffraction, transmission electron microscopy, magnetometry and ferromagnetic resonance to investigate the efficiency of above ion-beam methods in the synthesis of magnetoelectric nanocomposite materials. Our structural studies show that high-fluence implantation with Co⁺ ions results in the formation of cobalt nanoparticles with mean size of 5 nm in thin surface layer of monocrySTALLINE plate of BaTiO₃. On the other hand, larger nanoparticles of cobalt with sizes from 5 up to 40 nm are formed in polycrystalline BaTiO₃ matrix only after high-temperature annealing of BaTiO₃:Co composite film prepared by IBSD method. Both types of thin-film nanocomposite samples have similar magnetic hysteresis curves in the sample plane. However Co-implanted BaTiO₃ reveals strong uniaxial magnetic anisotropy for out-of-plane orientation, while BaTiO₃:Co nanocomposite film demonstrates almost isotropic magnetic response. Strong magnetoelectric effect are observed in Co-implanted BaTiO₃, and no magnetoelectric coupling are detected in BaTiO₃:Co nanocomposite film formed by IBSD with subsequent high-temperature annealing.

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1. Introduction

Materials revealing simultaneously ferroelectric and ferromagnetic properties are known as multiferroics [1,2]. The physical coupling between ferroelectric and ferromagnetic sub-systems in multiferroic materials leads to the appearance of the magnetoelectric (ME) effect. Namely, electric polarization in multiferroic materials can be changed by an application of external magnetic field or vice versa the magnetization of the material are changed under an action of electric field. These effects attract great scientific interest to magnetoelectric materials due to their potential applications in spintronics, sensors and memory devices, etc. However natural single-phase multiferroics reveal weak ME effects or it occurs at temperatures too low for practical applications. At the same time, composite multiferroics which combine two phases (ferromagnetic

with ferroelectric ones) show typically giant values of ME effect at room temperature and above [1,2].

A lot of various methods was used to synthesis of thin-film multiferroics based on ferroelectric matrix of BaTiO₃ with cobalt nanoparticles, e.g. pulsed laser deposition [3], rf magnetron sputtering [4], sol-gel method [5], chemical solution deposition [6] and laser molecular beam epitaxy [7]. Different magnetic responses and magnetoelectric coupling were observed in these nanocomposites materials in the dependence on synthesis method. Moreover ion-beam methods like ion implantation were used recently also to form nanocomposite layers of BaTiO₃ with iron impurity [8,9]. In the given work we used two ion-beam methods (ion implantation and ion-beam sputtering deposition) to form ferroelectric:ferromagnetic (BaTiO₃:Co) nanocomposite system. The results of structural, magnetic and magnetoelectric studies are presented to receive new knowledge about ion-beam ways of the synthesis of nanocomposite multiferroics and the nature of magnetoelectric coupling between cobalt nanoparticles and ferroelectric matrix of BaTiO₃.

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